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JULY 1994

COMPARISON OF MORTALITY LIMITS OF MARINE MAMMAL MANAGEMENT REGIMES

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National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii

ADMINISTRATIVE REPORT LJ-94-20

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**COMPARISON OF MORTALITY LIMITS OF
MARINE MAMMAL MANAGEMENT REGIMES**

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July, 1994

LJ-94-20



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INTRODUCTION

Marine mammals incur incidental mortality in commercial fishery operations. Several management schemes exist that allow marine mammals to be removed from the population with the goal of maintaining a healthy population. The National Marine Fisheries Service (NMFS) proposed a regime designed to allow depleted populations to recover, maintain the health of non-depleted populations and yet allow some mortality in fisheries. The Marine Mammal Protection Act Amendment of 1994 modified this scheme to regulate the incidental kill of marine mammals in commercial fishery operations. Although the 1994 Amendment uses the same principle as the NMFS proposal, quantitative terms remain undefined. This paper uses the 1992 NMFS proposal for comparative purposes. The International Whaling Commission (IWC) has developed a management regime that is similarly designed to insure healthy whale populations while simultaneously allowing animals to be commercially harvested. The IWC's Revised Management Plan has undergone extensive testing and revision to meet management objectives. The number of animals that may be harvested is calculated by a model called the catch limit algorithm (CLA). This document compares the mortality limits as calculated by each management scheme for a number of marine mammal populations. Populations were chosen for this comparison to illustrate the differences between the schemes and potential problems in implementing the schemes. This document does not address how well the management plans perform. Performance evaluation requires simulations to test performance against quantitative management objectives.

BACKGROUND

Abundance estimation. In order to understand the effect of mortality caused by fisheries on a population, we need to know the size of the population. However, no population of marine mammals can be counted in its entirety (a true census). Instead, the population is sampled and mathematical techniques are used to estimate abundance. The precision of abundance estimates depends not only on the sampling effort, but also on properties inherent to the populations themselves. In this paper we used estimates of abundance from marine mammal populations in California because these populations are representative of our current ability to estimate abundance. The method of abundance estimation depends on the type of marine mammal. Most seals and sea lions are photographed and counted during maximum abundance on land (breeding or moulting). Seasonal counts from animals on land are quite precise (coefficients of variation in abundance (cv's) often $< 10\%$). Because some unknown proportion of the population are at sea, the estimate would be precise but negatively biased. Estimates of the proportion at sea can be made to correct for the bias. Most whale and dolphin populations and some arctic seal populations must be estimated with distance sampling techniques (Buckland et al. 1993). Obtaining precise estimates (e.g. $cv < 0.3$) is frequently difficult.

The most common technique for abundance estimation is line-transect (Buckland et al. 1993). Observers on ships or planes traveling along survey lines record number of animals observed, species identity, and perpendicular distance from the survey line. Not all animals

are seen and observers have a better chance of seeing close animals than distant animals. These data are used to estimate the total number of animals. The quality of estimates made by line-transect depends in part on population size. Taylor and Gerrodette (1993) showed that the precision of the abundance estimate drops sharply with decreasing population size. Quality of the estimates also depends on how easily the animals can be seen. Some whales spend a high proportion of time below the surface. It is easier for an observer to miss such an animal because it may not be available to be sighted when the ship or plane passes. It is also more difficult to study the behavior of such diving animals because they are often in deep waters far from the coast. A correction factor and its associated variance should be applied to abundance estimates to account for the probability that the animal was not available for sighting. Unfortunately, the diving behavior of most whales is so poorly known that the correction factor cannot currently be estimated. The estimates for beaked whales and sperm whales are therefore known to be negatively biased (on average too small) but the magnitude of the bias is not known.

A less common technique for abundance estimation is called mark/recapture. Animals are individually identified by natural marks or scars recorded in photographs. Such individuals are considered 'marked'. When scientists photograph in subsequent years a certain proportion will be known 'marked' individuals and these animals are then referred to as 'recaptured'. The numbers of new individuals, marked individuals and recaptured individuals can be used to estimate abundance. Abundance of humpback whales in California can be estimated much more precisely with this method than with line-transect. Other species whose abundance estimate could likely be improved through mark/recapture techniques are killer whales and coastal bottlenose dolphins. Species that live farther from the coast, such as fin whales and blue whales, are candidates but it is logistically more difficult to 'mark' a high proportion of the population so the estimates are not as precise.

Incidental mortality estimation

In California, marine mammals are killed primarily in gillnet fisheries (Julian in press). Two pieces of data are required to make an estimate of how many animals are killed: the amount of fishing effort, and the number of animals killed per unit of effort. The latter figure is based on observations made by biological technicians placed aboard some commercial fishing vessels. In 1992, overall observer coverage was 13%, although some areas had coverage rates less than 8% (Julian in press). These figures are used to extrapolate to what the total kill might be. The lower the observer coverage, the more uncertain are the estimates of total kill.

METHODS

Both management schemes assume simple density-dependent single-species population dynamics (equation 1).

$$N_{t+1} = N_t + (\lambda_{\max} - 1)N_t \left[1 - \left(\frac{N_t}{K} \right)^\theta \right] \quad eq. 1$$

where N = population size,

t = time

$\lambda_{\max}$ = maximum discrete rate of population growth,

K = carrying capacity, and

θ = shaping parameter that determines maximum net productivity level.

Per capita growth rate is assumed to be non-linear such that the greatest change in reducing growth rate occurs when the population size is greater than half the population size at carrying capacity. Maximum Net Productivity Level (MNPL) is defined as the greatest net annual increment in population numbers or biomass resulting from additions to the population due to reproduction and/or growth less losses due to natural mortality (Gehring 1976).

Both schemes assume that the MNPL occurs at 60% of carrying capacity (K). Because both schemes seek to keep marine mammal populations as functioning parts of the marine ecosystem, the goal is to keep populations at or above MNPL.

The following are highlights of the major differences between the schemes which will be detailed later.

- 1) The CLA requires a higher quantity and quality of data: all catches of animals in the past and present are assumed to be known without error, abundance estimates must have variance estimates and be expressed as absolute numbers.
- 2) Historical catch data allows the CLA to estimate the status of the current population with respect to K . This allows a better estimate of population growth rate given population size which should allow a higher catch.
- 3) The CLA updates estimates of population growth rate based on new data on population size and catches. In other words, the CLA 'learns' from setting catch limits and observing response in population abundance.
- 4) The NMFS scheme can operate with very crude data, such as: abundance estimates with no variance estimates (such as maximum actual counts), no historical catch data, and current catch data with large amounts of uncertainty.
- 5) The NMFS scheme operates without knowing where K is relative to current population size. Estimates of population status (such as endangered or depleted) can be used to invoke safety factors that reduce allowed catch but knowledge of status is not necessary.

6) The NMFS scheme does not use historical information. Each catch calculation is made based only on the best current information on abundance, catch and growth rate at MNPL. There is thus no 'learning' in this simple calculation.

A more detailed description of the regimes follows.

The NMFS proposed regime

This regime is based on the goals of maintaining marine mammal stocks within their Optimum Sustainable Populations (OSP: populations between MNPL and K), while allowing incidental take in fisheries. It is also a system that utilizes parameters that scientists feel can be estimated with sufficient precision to assure the safety of populations. The regime is governed by the following equation:

$$PBRL = N_{MIN} R_{MNPL} F_R \quad eq. 2$$

where, PBRL = potential biological removal level,
 N_{MIN} = minimum population estimate,
 R_{MNPL} = population growth rate at MNPL, and
 F_R = recovery factor.

In the NMFS proposal, populations are categorized for purposes of assigning the recovery factor. Populations of unknown population level with respect to K (most populations) are given a recovery factor of 0.5 along with depleted or threatened species. The only species that qualify for the most conservative recovery factor (0.1) are those listed as endangered. For those listed within OSP, $F_R = 1$. N_{MIN} is defined as the best minimum abundance estimate which is either the lower 95th percentile of an abundance estimate or a minimum count. R_{MNPL} is either half the observed highest growth rate or (if growth rate is unknown) is a default value of 0.02 for cetaceans and 0.06 for pinnipeds. The 1994 amendment does not specify values for N_{MIN} or R_{MNPL} and allows F_R to take any value between 0.1 and 1.0 regardless of the status of the population. Presumably these levels will be given defined by NMFS regulations. For this comparison, the lower 95th percentile of a log-normal distribution of abundance is used for N_{MIN} . The safety factor described above was used.

The IWC Catch Limit Algorithm

The management objectives of the IWC Revised Management Plan are to assure the safety of whale populations while allowing a commercial harvest that is both as large as possible and as constant as possible. To meet the first objective, the Commission mandated that populations should not be harvested until they were greater than 54% of K and that populations should reach 72% of K in 100 years. Population growth rate at MNPL (called maximum sustainable yield rate) was set initially 'at the conservative value of 1% per year.

A series of simulations designed to test the performance of the models, called robustness trials, were conducted with the model "tuned" to these parameters. The model met objectives sufficiently well that the model (the CLA) was adopted by the scientific committee in 1992 (Report of the IWC 1992). Unlike the NMFS model, the IWC model uses data from abundance surveys and catches to modify the estimated growth rate. There is, therefore, feedback from incoming data to the parameters in the model.

The CLA requires sex-specific data on all historical catches (assumed to be known without error), a current abundance estimate, the coefficient of variation (cv) of the abundance estimate, abundance estimates made on a regular schedule not to exceed an eight year interval, and continuing data on catches (again assumed known without error). For several of the California populations examined in this paper, little or no historical catch data exist. For all cases, mortality estimates contain large degrees of uncertainty. The CLA requires historical catch data to estimate the current status of the population with respect to K . If historical catch information is omitted, the population is assumed to be at K . The reader should be aware that the CLA is being applied in this paper to cases for which it was not designed. Results presented here indicate the suitability of the current CLA to problems of incidental mortality but do not necessarily indicate potential performance problems within the realm for which it was designed: the commercial harvest of baleen whales.

As an exploratory exercise, we give results if the CLA was tuned to not allow harvest below 10% of K and to equilibrate at 60% of K (the assumed lower bound of OSP). Note that no robustness trials have been done with these values so performance cannot be assessed.

This paragraph documents changes that had to be made to the input parameters of the CLA for the purposes of comparing catch limits to potential biological removals. The catch limit algorithm makes numerous initial assumptions. Table 1 shows the original assumptions and the values used in this comparison. Table 2 gives the tuning parameters and levels for the different growth rates and internal protection levels. The tuning procedure is time consuming so only 100 trials were run. Although the resulting tuning parameters and levels are approximate, the slight changes anticipated with more thorough tuning would not greatly alter the results.

PARAMETER	CLA	CETACEANS	PINNIPEDS
TRUE MSY RATE	0.01	0.02	0.06
MAX MSY% (PPROB)	0.05	0.05	0.10
NO. OF MSY STEPS (PNYSTP)	5	5	10

Table 1. Parameter changes made to adjust tuning of the CLA. Altered files used in program CATLIM.EXE were: PARS.DAT, T1-D1.DAT, and the tuning files (see Table 2).

GROWTH RATE	INTERNAL PROTECTION LEVEL	TUNING LEVEL	TUNING PARAMETER
0.02 (cetaceans)	0.54	0.720	0.540
0.02	0.10	0.597	0.290
0.06 (pinnipeds)	0.54	0.722	0.585
0.06	0.10	0.598	0.280

Table 2. Tuning parameter estimates obtained from the program TUNE.EXE using 100 trials and appropriate files from Table 1.

RESULTS

Comparison of the CLA catch limits to calculated PBRLs

We chose four populations to compare the two regimes: California sea lions (Zalophus californianus californianus), the California population of harbor seals (Phoca vitulina richardsi), the central California population of harbor porpoise (Phocoena phocoena), and the California population of common dolphins (Delphinus delphis). Past mortality estimates are given in Table 3. Abundance estimates or counts are given in Table 4.

Two difficulties are immediately apparent for using the CLA to establish allowable incidental take: precision (cv) is not available for the pinniped populations, and data are missing for mortality. As mentioned, a large proportion of the pinniped populations can be counted on land at certain seasons. The proportion remaining at sea is only approximately known and probably varies from year to year according to oceanographic conditions (especially El Niño years). For the purposes of this paper, the coefficient of variation (cv) was set to 0.1 for pinnipeds. Missing mortality data is also problematic. Harbor seal and harbor porpoise data previous to 1983 were crudely estimated by using historical effort data and rates of mortality at different effort levels from observer programs started in the late 1980s (Boveng 1988, Barlow and Hanan in press). This could be done with other species but does not assist in the larger problem for pinnipeds of intentional historical take. All pinniped populations are recovering from a period of intense hunting that brought populations to very low levels but during which numbers of harvested animals was not recorded. In order to use the CLA as a management tool, extensive research would need to be done to estimate historical catches. It is not certain whether such records could be accurately reconstructed, and certainly they would contain error.

YEAR	CA SEA LIONS	CA HARBOR SEALS	CENTRAL CA HARBOR PORPOISE	CA COMMON DOLPHINS
1968		70 ⁷		
1969		256 ⁷	28 ⁸	
1970		190 ⁷	21 ⁸	
1971		419 ⁷	46 ⁸	
1972		565 ⁷	62 ⁸	
1973		178 ⁷	19 ⁸	
1974		353 ⁷	39 ⁸	
1975		696 ⁷	77 ⁸	
1976		869 ⁷	96 ⁸	
1977		676 ⁷	74 ⁸	
1978		1131 ⁷	124 ⁸	
1979		1629 ⁷	179 ⁸	
1980		2053 ⁷	226 ⁸	
1981		2573 ⁷	283 ⁸	
1982		2015 ⁷	222 ⁸	
1983	3427 ¹	834 ¹	303 ⁹	
1984	2244 ¹	1138 ¹	226 ¹⁰	660 ¹²
1985	2207 ¹	1886 ¹	226 ¹¹	1060 ¹²
1986	4288 ²	2028 ²	197 ²	
1987		903 ⁶	59 ⁶	
1988	3753 ³	1115 ³	91 ³	509 ³
1989	2315 ³	746 ³	92 ³	490 ³
1990	2753 ³	890 ³	84 ³	430 ³
1991	1892 ⁴	559 ⁴	38 ⁴	373 ⁴
1992	3379 ⁵	1136 ⁵	44 ⁵	356 ⁵

Table 3. Mortality estimates with the following sources: 1) Hanan et al. 1988, 2) Hanan and Diamond 1989, 3) Perkins et al. 1992a, 4) Perkins et al. 1992b, 5) Julian in press, 6) Konno 1990 7) Boveng 1988, 8) Barlow and Hanan in press, 9) Diamond and Hanan 1986, 10) Hanan et al. 1986, 11) Hanan et al. 1987, 12) Diamond et al. 1987. Some mortality estimates are not made for calendar years. An estimate made for a split year (such as 1985-1986) is recorded in the earlier year (1985 in this example).

YEAR	CA SEA LIONS		CA HARBOR SEALS		CENTRAL CA HARBOR PORPOISE		CA COMMON DOLPHIN	
	ABUNDANCE MINIMUM (NO CV)	BEST ABUNDANCE ESTIMATE (NO CV)	ABUNDANCE MINIMUM (NO CV)	BEST ABUNDANCE ESTIMATE (NO CV)	ABUNDANCE MINIMUM (LOWER 95%)	MEAN ABUNDANCE ESTIMATE	ABUNDANCE MINIMUM (LOWER 95%)	MEAN ABUND. ESTIMATE
1975	24078	50049						
1976	23786	49443						
1977	23178	48179						
1978	33842	70345						
1979	28904	60081						
1980	28994	60268						
1981	33974	72698						
1982	39554	82219						
1983	25466	52935						
1984	28402	59038	14164	19830				
1985	30874	64180	14878	20829				
1986	36028	74889	15632	21885				
1987	40276	83719	19446	27224				
1988	39978	83099	18042	25259				
1989	47506	98748	20313	28438	2481	3810		
1990	53408	111016	18483	25876				
1991			23089	32325			142514	260897
1992								

Table 4. Counts or abundance estimates for selected California marine mammal populations. Sea lion data are taken from Lowry et al. 1992. The minimum count is twice the maximum pup count. The best abundance estimate multiplies the pup count by a factor of 4.16 as described in Lowry et al. 1992. Harbor seal data are taken from Hanan et al. 1992 for the 1984-1991 period and from Hanan 1993 for the 1992 estimate. The minimum estimate is the maximum number counted during the moult. The best abundance estimate corrects for the proportion not visible by multiplying by a factory of 1.4 (Boveng 1988). Harbor porpoise estimates are from Barlow and Forney 1993. Common dolphin estimates are from Forney and Barlow (in press).

Table 5 contains the estimates of catch limits/PBRLs for the selected species. About the only general conclusion from these results is that PBRLs are usually less than catch limits from the CLA. The expected results from the CLA are that the less stringent management objectives, which allow harvest when populations exceed 10% of K and seeks to equilibrate at 60% of K, will always result in higher catch limits than the conservative 54/72 tuning. It is also expected that no catch, which indicates that the population is unexploited, should result in higher catch limits than populations that have been exploited. Neither of these hold true. CLA results will therefore be considered on a case by case basis.

POPULATION	PBRL	CLA 54/72		CLA 10/60	
		ALL CATCH	NO CATCH	ALL CATCH	NO CATCH
SEA LION	1602	8280	4924	3432	2007
HARBOR SEAL	693	2993	1621	1470	742
HARBOR PORPOISE	25	17	44	35	35
COMMON DOLPHIN	1470	1953	2241	1510	1553

Table 5. PBRL values and catch limits calculated using both the more conservative IWC tuning (54/72) and an experimental tuning (10/60). 'ALL CATCH' indicates that all catch data in Table 3 were used in the CLA program. 'NO CATCH' indicates that no catch data were used in the CLA program.

DISCUSSION

California sea lions

Sea lions exemplify the non-intuitive catch limits given by the CLA: the less conservative tuning gives more conservative catch limits, and the lack of historical catches gives lower catch limits. It is also clear that the CLA is very sensitive to whether catch data are included and to the tuning level. The explanation of why the CLA yields such counter-intuitive results is unknown. There are two violations of the assumptions of the CLA that may contribute. First, true historical removals are known to have been so large that the population was reduced to levels far below K. Quantitative catch estimates by year and sex are not available and were therefore not given in the file of historical catches used in the program to calculate catch limits. Second, the growth rate for sea lions is far higher than that for cetaceans. Modifications were therefore made to CLA files to allow for this higher

growth rate (Table 1) but because the CLA was tuned to give the best performance for baleen whales, it may be compromised by such adjustments.

Harbor Seals

Catch limits for harbor seals in California had a similar pattern to sea lions. Historical catch estimates had been made over a longer period for harbor seals, yet there was a smaller proportional difference between using catch data and not using these data than there was for the sea lions. Eliminating the safety factor ($F_R = 0.5$ for both cases) would have made PBRLs more similar to catch limits for both pinnipeds.

Harbor porpoise

Harbor porpoise are probably come the closest to meeting the assumptions of the CLA: there has been no directed harvest of animals, and incidental take is probably close to the values in Table 3. The decreased catch limit using the catch data (18) compared to not using the catch data (44) with the 54/72 tuning is what would be expected. When catch data are used, the increase in catch limit when tuning to the less stringent 10/60 level is also expected. However, comparing the 'all catch' to 'no catch' catch limits within the 10/60 CLA tuning does not make sense.

Common dolphin

The common dolphin has the fewest mortality estimates and only a single abundance estimate. Although it follows the same counter-intuitive pattern of allowing a smaller catch with the less conservative tuning (10/60) as seen in the sea lion, the differences between the catch limits are much smaller.

CONCLUSION

Calculating PBRLs was unproblematic. The CLA, however, requires data that are currently unavailable: abundance cv's for all species, historical catches without error, current catches without error. Obtaining cv's for all abundance estimates may be possible but will require considerable effort. It will not be possible to estimate incidental take without error either in the past or in the present.

Results from the CLA are very difficult to interpret. The authors believe that modifications would have to be made to the CLA and to the robustness trials before the CLA could be used for species primarily affected by incidental fishery mortality. Reconstructions of past incidental takes would have to be made for each species. For species that historically have been taken by fisheries which are technologically the same today, such as the harbor porpoise, reasonable estimates may be possible. For many pinnipeds that probably had high levels of mortality because of activities that no longer occur at the same magnitude (such as

intentional shooting, live capture, etc.) estimation of mortality would be difficult and uncertain.

Therefore, modifications and testing need to be conducted before the CLA can be evaluated. It may be worth considering incorporating some of the techniques and philosophy of the CLA into the NMFS proposal at some future time. For example, the feature of incorporating abundance and removal data into the estimation of R_{MNPL} allows the data to slowly modify the estimate rather than requiring a decision rule about when to abandon default values for 'known' values. Perhaps this calculation could also be used to revise the recovery factor as an ongoing data driven process.

Because a finely-tuned management scheme such as the CLA will probably not be appropriate for management of incidental fishery mortality of marine mammals in U.S. waters, it is pertinent to consider which species are likely to require active management given the NMFS proposed regime. It is then possible to decide whether the species is highlighted for management because 1) it probably requires protection, or 2) inadequate knowledge about the species may be generating a false assessment of the magnitude of the problem. The NMFS proposal directly addresses the problem of precision by using a minimum estimate of abundance in calculating PBRLs. The arbitrary value used for the minimum abundance estimate (the lower 95% confidence limit) performs adequately under a number of possible sources of error (Taylor 1993). It does not account, however, for bias in abundance estimates. Table 6 shows PBRLs for most marine mammals in California waters, mortality for 1992 and whether bias is likely. Potential problem species are indicated by an arrow followed by a letter to indicate the possible type of problem: A--likely mortality exceeds PBRL, no known problems with estimates, B--PBRL less than one individual/year so an unusual accident (ship strike) could exceed PBRL, C--the animal has long dive times such that animals are probably missed on the trackline because they were unavailable to be observed and abundance estimates could be negatively biased, D--animals are difficult to see and/or identify such that the animals may have been available to be seen but were not perceived leading to a possible negative bias in abundance estimates, E--although a correction factor was applied to correct for the proportion of animals not available for counting, the proportion could be in error and thus bias the abundance estimate. Note that a likely negative bias does not indicate that the actual mortality is less than the actual PBRL based on an unbiased abundance estimate. It is possible that if the bias were corrected for, that the mortality would still be too high. Table 6 indicates where research needs are most urgent to be able to address which populations are truly in need of take reduction.

Thus, although the NMFS proposal has clear merit in that it requires only the data that are available, it will not be a regime that can unequivocally choose the correct populations for management action. This is primarily because of the problem of bias in abundance estimates. Any management scheme must treat the problem of bias. Given the amount that estimated mortality exceeds PBRL for beaked whales and pygmy sperm whales, there appears to be real cause for concern. NMFS may give priority to research that addresses these bias problems, such as gathering data on the distribution of the length of dive

POPULATION	PBRL (NMFS)	1992 MORTALITY	RATIO MORTALITY/PBRL	PBRL (NO RECOVERY FACTOR)
harbor porpoise (central CA)	25	44	1.8 ← A	50
harbor porpoise (all CA)	96	44	0.5	191
Dall's porpoise	801	8	0.01	801
Pacific white-sided dolphin	851	23	0.03	851
Risso's dolphin	234	38	0.2	234
bottlenosed dolphin (offshore)	11	23	2.2 ← A	21
striped dolphin	175	0	0.0	175
common dolphin (short & long-beaked forms)	1470	356	0.2	2939
northern right whale dolphin	72	15	0.2	145
killer whale	.5	0	0.0 ← B	1
Baird's beaked whale*	.1	0	0.0 ← B,C	.1
Cuvier's beaked whale*	4	45	11.4 ← C,D	8
mesoplodon species*	.6	23	38.3 ← B,C,D	1.2
beaked whales*	12	91	7.7 ← C,D	24
pygmy sperm whale*	2	23	10.5 ← C,D	4
sperm whale*	.6	0	0.0 ← B,C	6
Bryde's whale	.2	0	0.0 ← B	.2
fin whale	.6	0	0.0 ← B	6
blue whale	2	0	0.0	22
minke whale	1	0	0.0	6
humpback whale	.6	0	0.0 ← B	2
California sea lion*?	1602	3379	2.1 ← E	3204
harbor seal*?	694	1136	1.6 ← E	1387
northern elephant seal*?	1284	165	0.1	2571

Table 6. Potential biological removals and mortality for 1992. Minimum abundance estimates that are likely to be negatively biased are indicated by an asterisk. Sources for abundance estimates are: for harbor porpoise--Barlow and Forney 1993, for other cetaceans--Forney in prep., sea lions--Lowery et al. 1992, harbor seals--Hanan 1994, Northern elephant seal--Barlow et al. 1993.

times. When mortality exceeds PBRLs for pinnipeds in California, the problem clearly lies with the calculation of PBRL because it is known that populations have continued to recover despite incidental mortality in fisheries. It is likely that the default growth rate is too low. It is also possible that abundance estimates are still negatively biased because a higher proportion than currently estimated are not on land and available for counting. The problem with having less than one PBRL allowed per year could be solved administratively by allowing the PBRL to span a multiple year period.

The Marine Mammal Protection Act Amendment of 1994 does not specify the values for any of the parameters in equation 1. The recovery factor is allowed to vary from 0.1 to 1.0 and is not tied to legal status such as whether the species or population is depleted, threatened or endangered. The last column in Table 6 shows the PBRLs with a recovery factor of 1.0. Presently available minimum population estimates reflect the lower 95% confidence limits for the cetaceans and this is the value used to calculate the PBRLs in the last column. Although the value to be used for the minimum population estimate may also be changed, these PBRL values indicate again that the most problematic species are the whales that are long-diving, often difficult to see and identify (beaked whales and pygmy sperm whales).

In order to calculate PBRLs, NMFS must specify values to be used for the parameters. Lessons can be learned from the approach taken by the International Whaling Commission in evaluating the performance of the CLA. The IWC scientists examined the performance of the management scheme via computer simulations that examined the types of errors that may occur with the data. Performance was then evaluated using quantitative management objectives. Such objectives have not been specified for U.S. marine mammals to date. An example of such an objective would be: populations shall be managed so that they reach 60% of K within a period of 50 years for cetaceans (and are maintained above that level) and within 30 years for pinnipeds with a probability of 0.95. Performance of various combinations of parameters could then be assessed according to how well they met the quantitative objective. Therefore, although the CLA is not appropriate for management of U.S. marine mammals, techniques of performance evaluation as well as some of the modeling philosophy could be.

ACKNOWLEDGEMENTS

Thanks to Jay Barlow and Rod Hobbs for thoughtful reviews. B. Taylor was supported as a National Research Council Associateship through funding provided by the Office of Protected Resources of the National Marine Fisheries Service.

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